CHAPTER 4

COLLIMATION

LEARNING OBJECTIVES

Upon completing this chapter, you should be able to do the following:

1. Describe the theory of radar collimation.

2. Describe the requirements for radar collimation of the Tartar/SM1 missile fire-control system.

3. Identify the basic equipment used during radar collimation with a shore tower.

INTRODUCTION

The collimation of fire-control radars is one of the major steps toward achieving a successful battery alignment. This chapter discusses the theory of radar collimation, collimation requirements, shore tower-based operation and requirements, and test equipment and procedures used in collimation and correlation, especially as applied to the Tartar (Standard) Guided-Missile, Fire-Control System (GMFCS). Keep in mind that although the specific equipment used on board your ship may be differ from the example used in this chapter, the purpose is still the same; that is, to achieve a successful battery alignment.

RADAR COLLIMATION THEORY

Collimation is an optical electronic technique used to establish parallelism between the radio-frequency (RF) beams radiated from a radar antenna or between the RF beam and the optical line-of-sight (LOS) axis of the antenna. This optical axis is called the *boresight axis* and is established with the optical telescope.

Radar collimation is the parallel alignment of the radar beam axis and the optical axis of the radar antenna. It can be accomplished by using either a shore-based tower or a portable ship's tower that supports both an optical target and a radar horn antenna.

The horn antenna is connected to the RF power-measuring equipment and is properly positioned in relation to the optical target. The horn antenna displacement, relative to the optical target, is determined by the relative displacement of the two axes (optical and RF), as measured at the radar.

The parallelism of the two axes is checked or adjusted by training and elevating the radar antenna until the cross hairs of the optical sight intersect the optical target. At that time, maximum RF energy should be directed into the horn antenna, as measured by the power-measuring equipment. If it is not, the axes will not be collimated, and appropriate adjustment procedures must be accomplished, as one axis must be aligned to the other axis until they are parallel.

The optical LOS or boresight axis is the fixed reference for some radars, while for others, it is not. On radars where the boresight axis is the fixed reference, the RF beams are aligned to the boresight axis. On radars where the foresight axis is not fixed, the telescope is moveable and is adjusted parallel to the reference RF beam. Figure 4-1 shows a radar collimation configuration with a shore-based tower setup.

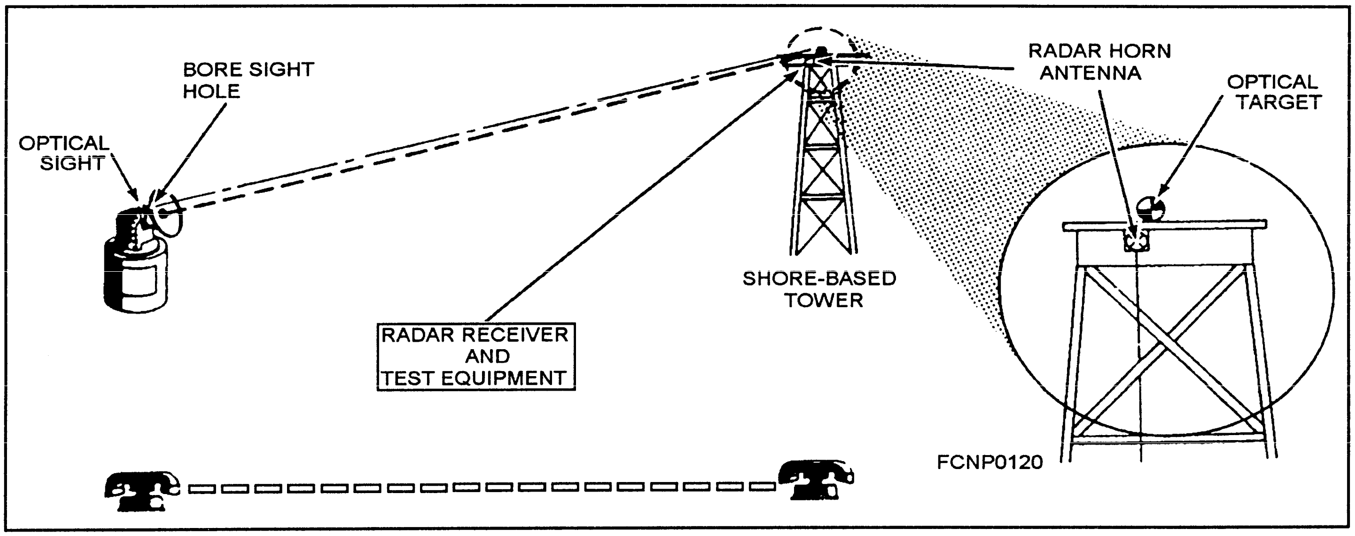


Figure 4-1.—Radar collimation with a shore-based tower setup.

TARTAR GMFCS RADAR COLLIMATION REQUIREMENTS

Because different types of radar are used in the missile and gun systems, the collimation requirements for each radar are different. This section briefly discusses the requirements for the Tartar GMFCS.

The primary radar for the Tartar GMFCS is the Radar Set AN/SPG-51C/D. It is an automatic target-acquisition and missile-guidance radar set that uses C-band, pulsed-Doppler techniques for target tracking and an X-band continuous-wave (CW) illuminator to provide guidance for the semiactive homing Tartar missile.

As shown in figure 4-2, the C-band and X-band feed horns on the radar antenna are effectively located at the same feed point so that the track and CW illuminator RF beams are parallel, within specified tolerance. A wide continuous-wave illuminator (CWI) reference beam is also generated by the X-band horn, which is located in the center of the antenna reflector to fill in any nulls in the CWI main beam and to provide missile rear reference information. The beam relationships are shown in figure 4-3.

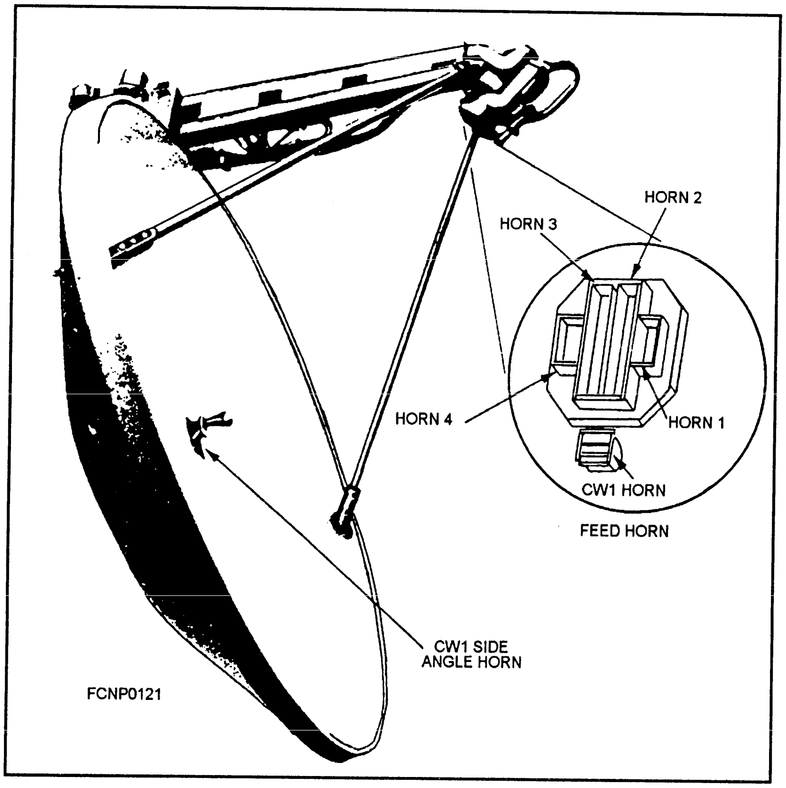


Figure 4-2.—Tartar radar C-band and X-band feed horns.

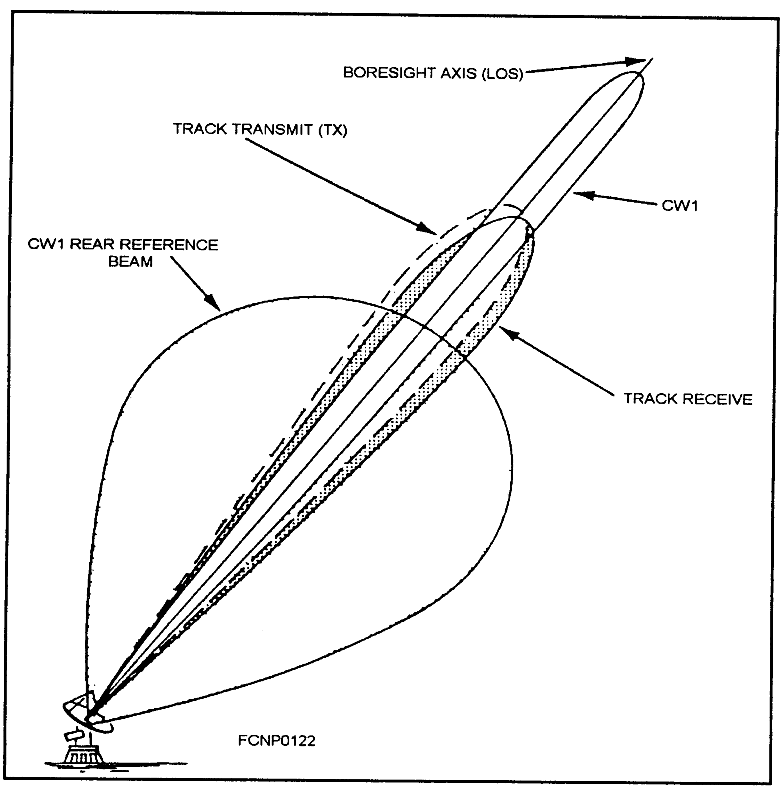


Figure 4-3.—Tartar radar CWI beam relationships.

For rapid target acquisition and proper tracking, the track radar beam must be parallel to the boresight axis, which is referenced to the ship's weapons system by benchmarks. An appreciable error between the axis along which the radar effectively receives the return pulses (called the track receive or the *TR axis)* and the axis along which the radar transmits (called the *track transmit* or the *TX axis)* reduces the rapid acquisition capability of the radar. An error between the TR axis of the tracking radar and the axis of the CW illuminator impairs Tartar missile performance by reducing target illumination power.

Collimation of the Tartar radar consists of determining the error between the RF beam axis and the boresight axis and the errors between the RF beams themselves.

In addition to determining the relative positions of the RF beam axis, collimation operations should ensure that

- the angle-error signals are generated properly in each quadrant when the antenna is off target axis,
- the specified angle-error sensitivity of the angle tracking circuitry is obtained, and
- the beam pattern is symmetrical.

Figure 4-4 shows Tartar radar collimation axes.

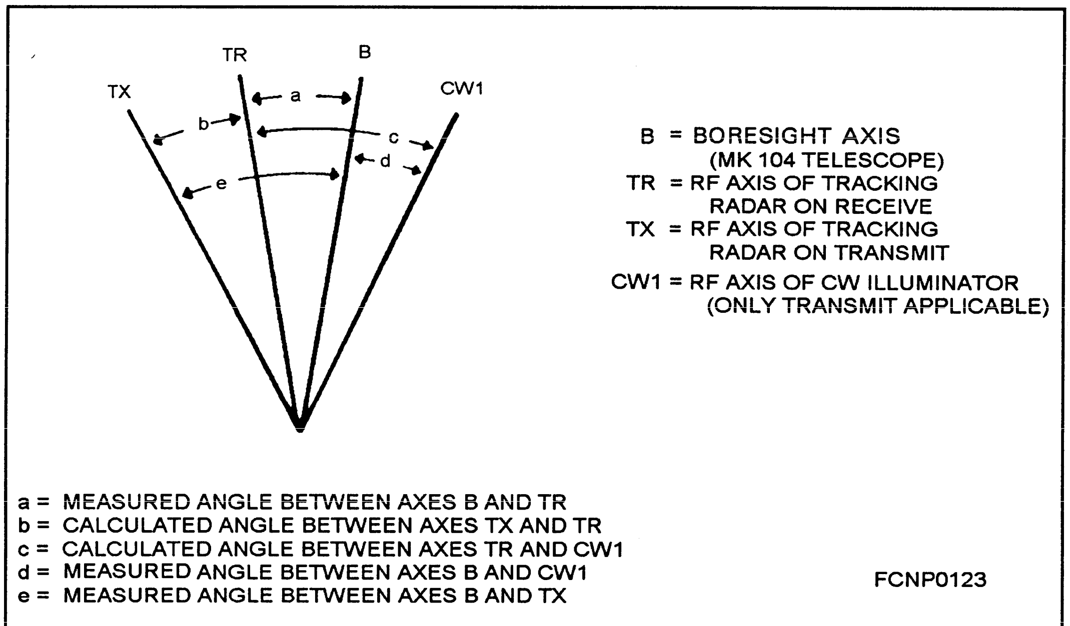


Figure 4-4.—Tartar radar collimation axes.

RADAR COLLIMATION SHORE TOWERS

Radar collimation shore towers are designed primarily to check antenna beam collimation and RF characteristics of GMFCSs. They also provide facilities for collimation and beacon checks of gunfire-control radars and RF alignment (azimuth only) of the three-coordinate search radars.

A radar collimation shore tower is 130 to 250 feet high with a moveable array on which test antennas and associated optical targets are mounted. Waveguide and coaxial transmission lines connect the antennas on the tower array to an equipment room at the base of the tower.

The equipment room contains all the test equipment necessary to perform collimation and to check RF characteristics on the various guided-missile/ gunfire-control radars and the three-coordinate search radars found in the fleet. Figure 4-5 depicts a collimation tower.

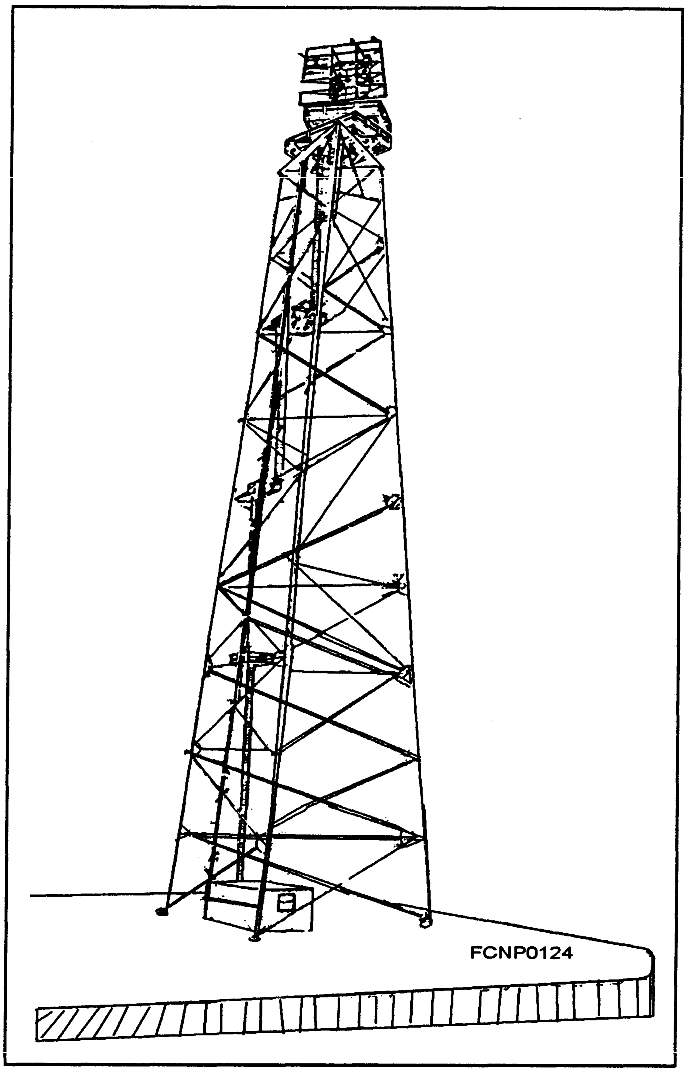
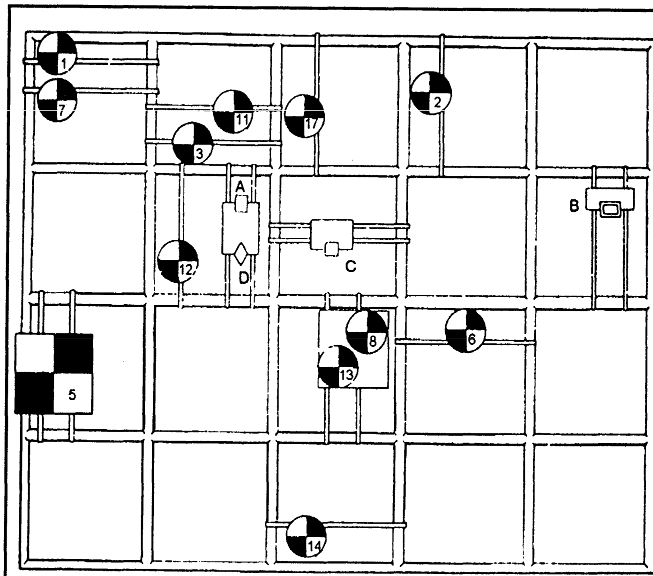


Figure 4-5.—Collimation tower.

TOWER ARRAY

The tower array can be moved in train and elevation by either powered or manual means. The array consists of a metal frame (usually constructed from aluminum piping) and test antennas and optical targets required for shore-tower checkout of shipboard radars. The test antennas and the optical targets are mounted on the metal frame and spaced to correspond to the spacing between the center of radiation (RF axis) and the telescope or boresight axis of each shipboard radar. This eliminates parallax errors caused by the small ship-to-tower distance involved during normal tower operations.

The targets are illuminated by either back lighting or floodlights. The four test antennas and their characteristics, the associated optical targets, and the applicable radar systems that can be tested are summarized in figure 4-6.



A

ARRAY USAGE

SYSTEM	RADER	BEAM	ANTENNA	TARGET
TERRIER	AN/SPG-55	GUIDANCE	A	1
		CAPTURE	A	2
		TRACK	A	1
		CW1	D	7
		CUSTER	B	3
		DOPPLER	B	1
TARTAR	AN/SPG-51	TRACK	C	6
		CW1	D	8
		TV		5
[redacted]				
MK 86	AN/SPG-60	TRACK	D	13
		TV		17
MK 92		TRACK		11(STR IN LINE) 12 (CAS) 13 STR MK 104
		TV(IF INTL)		17

TEST ANTENNAS

ANTENNA	MODEL	GAIN	POLARIZATION	TYPE
A	AV4517 OR 56C1	18db	VERTICAL	C-BAND HORN
B	MICROLAB/ FXR X638A	22db	VERTICAL	X-BAND HORN
C	AV 4517 OR 56C1	18db	HORIZONTAL	C-BAND HORN
D	AEL H6000	8.2db	CIRCULAR	X-BAND HORN

FCNPO125

B

Figure 4-6.—(A) Standard tower array; (B) Array usage.

COLLIMATION TEST EQUIPMENT

Each collimation tower is equipped with a set of test equipment for specific tower use. This equipment is stowed in the tower equipment room. The major items include

M. Radar Test Set AN/SPM-9,

Range Calibrator Set AN/UPM-115,

Range Calibrator Set AN/SPM-6,

Radar Beacon Test Set AN/TPN-7 or AN/UPN-32,

Continuous-Wave Acquisition and Track (CWAT) Tower Transponder, and

Microwave Power Meter HP 430.

Some of this test equipment is in the process of being replaced and can be identified in the combat systems alignment manual that is specific to your class of ship. A number of additional items of general-purpose test equipment, such as oscilloscopes, signal generators, coaxial cables, directional couplers, and variable attenuators are also used at both the tower and aboard the ship.

RADAR COLLIMATION PROCEDURES

Shore-tower checks between regular overhaul periods are generally not performed except when the Naval Sea Systems Command (NAVSEA) or the Naval Ship Weapon Systems Engineering Station (NSWSES) specifies a shore-tower check as a result of extensive shipyard or alteration work, or after a microwave casualty occurs that requires microwave component replacement. On ships outfitted with a portable ship's tower, the need for shore-tower service is established when ship tower checks indicate that tolerances are exceeded or when correlation data is in question.

Certain environmental condition requirements must be complied with before tower operation. These include the amount of ship motion and the weather conditions under which the collimation procedures are performed.

Because ships must be tested while afloat, certain methods of limiting the motion are used. One method consists of securing the ship snugly to a pier or dock or, in certain cases where excessive ship motion is created because of tide changes, by using various weighing methods, as shown in figure 4-7, to reduce the ship's motion.

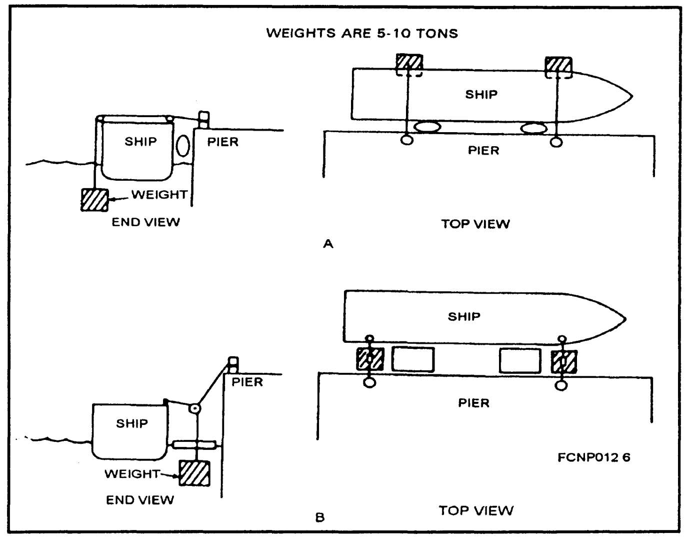


Figure 4-7.—Ship weighting for reducing motion.

Weather conditions must be considered because of the adverse effects they can have on collimation tests. For example, visibility between ship and tower, wind and water action, and heat radiation can affect collimation tests. Visibility should be good between the ship and the tower. High winds or rough water can cause ship motion to be so excessive as to invalidate test results. If refraction due to heat radiation is observed while viewing an optical target, consideration should be given to rescheduling operations at an earlier hour of the following day.

The Tartar/SM1 weapons system is employed aboard several classes of ships. Each class of ships has a unique configuration of the weapons system components. Consequently, each class has its own specific collimation procedures.

This section discusses track-receive axis collimation, track-transmit axis collimation, and CWI axis collimation. These procedures are discussed only in a general way and do not address specific procedures for any particular class of ships.

TRACK-RECEIVE AXIS COLLIMATION

In track-receive (TR) axis collimation, the angle-error null method of measurement is used to determine the error between the track receive axis and the borescope axis of the AN/SPG-51C/D radar. At the shore tower, the Range Calibrator Set AN/SPM-6 is connected to transmission line C, which connects to antenna C on the tower array. Aboard ship, the AN/SPG-51 radar director is manually pointed toward the shore tower.

The director is not energized during any AN/SPG-51C/D radar collimation checks. When the director is in the required position, the AN/SPG-51C/D radar track transmitter is set to RADIATE, thus triggering the AN/SPM-6 range calibrating set at the shore tower. When triggered by the radar signal, the AN/SPM-6 begins transmitting back to the radar set RF pulses identical to the pulses being received, which, when received by the radar, appear as target video on the A-scope of the radar operator's console. Only three to five of these video pulses are observable on the A-scope because of the high pulse-repetition frequency (PRF) of the radar set.

The radar is placed in range track when video pulses are observed on the A-scope. This is accomplished by gating one of the returned pulses. A Doppler target is required to ensure that an angle-error output voltage is generated whenever the antenna (director) is manually moved off target. This requirement is accomplished by setting the CLUTTER REJECT switch on the operator's console to the 0 KT position. The traverse- and elevation angle-error voltages generated from the angle-error detector module of the AN/SPG-51C/D data converter are monitored by two voltmeters.

With the radar in track, the director is held stationary on target (brakes set) in one axis (TRAIN or ELEVATION) and rocked through the angle error null point (as indicated by the variable time voltmeter [VTVM]) in the other axis. The mark method is used to correlate angle-error null voltage readings with borescope readings. The borescope readings (in roils) are taken with respect to the AN/SPG-51C/D track radar optical target 6 or 10 on the tower array. A minimum of 20 nulls and the borescope readings are taken to determine the collimation error between the TR axis and the borescope axis. This procedure is then repeated for the other axis (traverse or elevation).

Before actually determining the TR axis error by the angle-error null method, checks should be made to determine that an angle error of proper sensitivity (1 voltage per millimeter [v/mil]) can be generated in each quadrant and that conical-scan-on-receive-only (COSRO) phasing is correct (minimum crosstalk) to preclude offset of the angle-error null.

TRACK-TRANSMIT AXIS COLLIMATION

In track-transmit (TX) axis collimation, the beam-pattern plot method of measurement is used to determine the error between the track-transmit axis and the borescope axis of the AN/SPG-51C/D radar. There is no requirement for test equipment aboard ship during the performance of this test. The test setup aboard ship consists of placing the track transmitter in the RADIATE mode, pointing the radar antenna (director) toward the shore tower, and centering the AN/SPG-51C/D track radar optical target 6 or 10 in the borescope.

In the tower, the average power meter is connected through the calibrated attenuator (C-band) to the waveguide line connected to antenna C on the array. Attenuation is adjusted to allow the track transmitter power to be read conveniently on the power meter (in decibels or milliwatts, as preferred). After establishing a reference point (reading of maximum power) by coaching the director operators aboard ship via sound-powered telephone, the track transmitter output power at the tower as the antenna (director) is held stationary in one axis (traverse or elevation) and moved off target in the other axis is plotted. The offset readings in roils are given by the borescope observer aboard ship.

Usually, a 30-mil excursion on each side of the maximum power point is sufficient. After plotting the power readings to offset in mils on a graph, a horizontal line connecting the half-power points (3 decibels down) is drawn. By bisecting this line and observing where the bisecting line intercepts the mils axis, you can determine the collimation error between the TX axis and the boresight axis. Extreme care must be exercised in taking each power reading to obtain accuracy with this method.

The borescope operator may have to give several marks at each offset position to obtain a good average power reading. Figure 4-8 shows the TX axis beam-pattern plot-method graph.

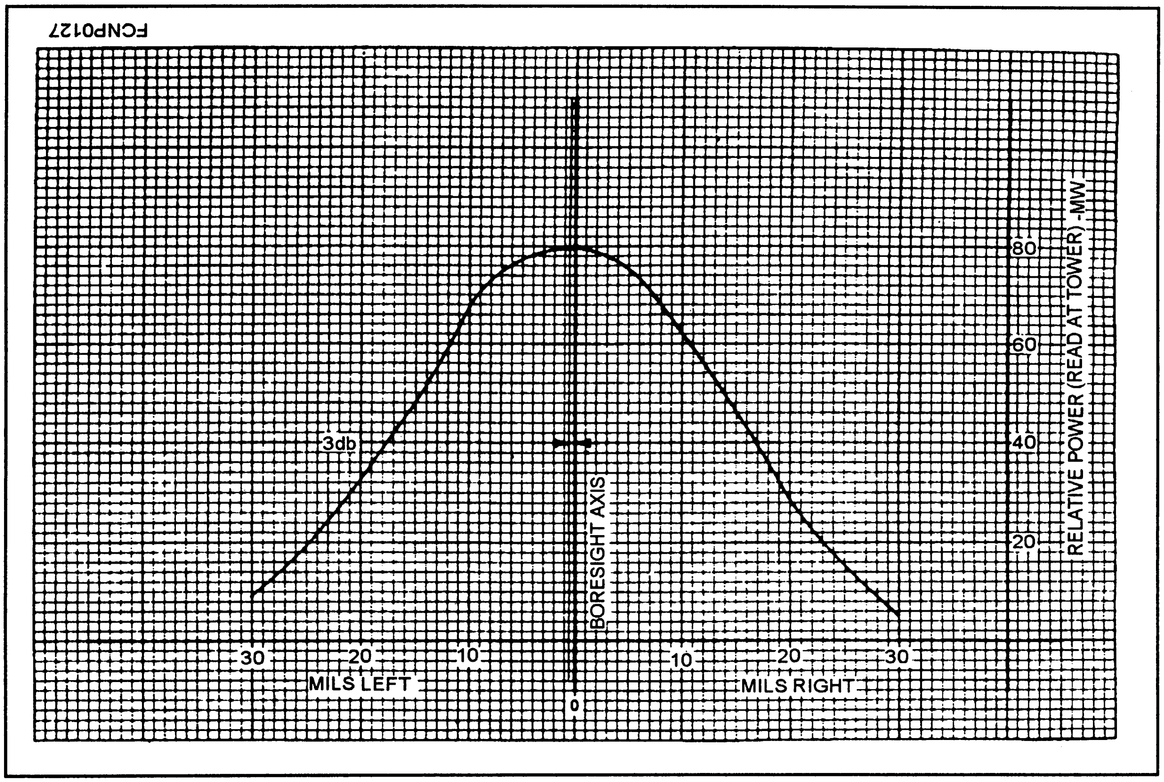


Figure 4-8.—Beam-pattern plot-method graph.

CWI AXIS COLLIMATION

The beam-pattern plot method of measurement is used to determine the error between the CWI axis and the borescope axis of the AN/SPG-51C/D radar. There is no requirement for test equipment aboard ship during the performance of this test.

The procedures for determining CWI axis error are similar to those for the track-transmit axis, except that the CWI radar is used.

The test setup aboard ship consists of placing the CWI transmitter in RADIATE, pointing the radar antenna toward the tower, and centering the CWI optical target 8 in the borescope.

In the tower, the average power meter is connected through the calibrated attenuator (X-band) to the X-band waveguide line going to antenna Don the tower array. The attenuator is adjusted to allow the C WI power to be read conveniently on the power meter (in decibels or milliwatts, as preferred). After establishing a reference point (maximum power reading) by coaching the director operators aboard ship, the CWI power at the tower as the antenna (director) is held stationary in one axis (traverse or elevation) and moved off target in the other axis is plotted. The offset readings in roils are given by the borescope observer aboard ship.

A power plot curve is drawn and the 3-decibel down points are connected by a horizontal line. The bisector of this line intercepts the mils axis of the graph to provide the collimation error similar to the TX procedures. Usually, a 15-mil excursion each side of the maximum power point is sufficient. After all three RF beam axes have been established, their data is plotted together on a beam position summary graph, as shown in figure 4-9. From their relative positions, the collimation errors can be determined and any corrective action, if required, can be made.

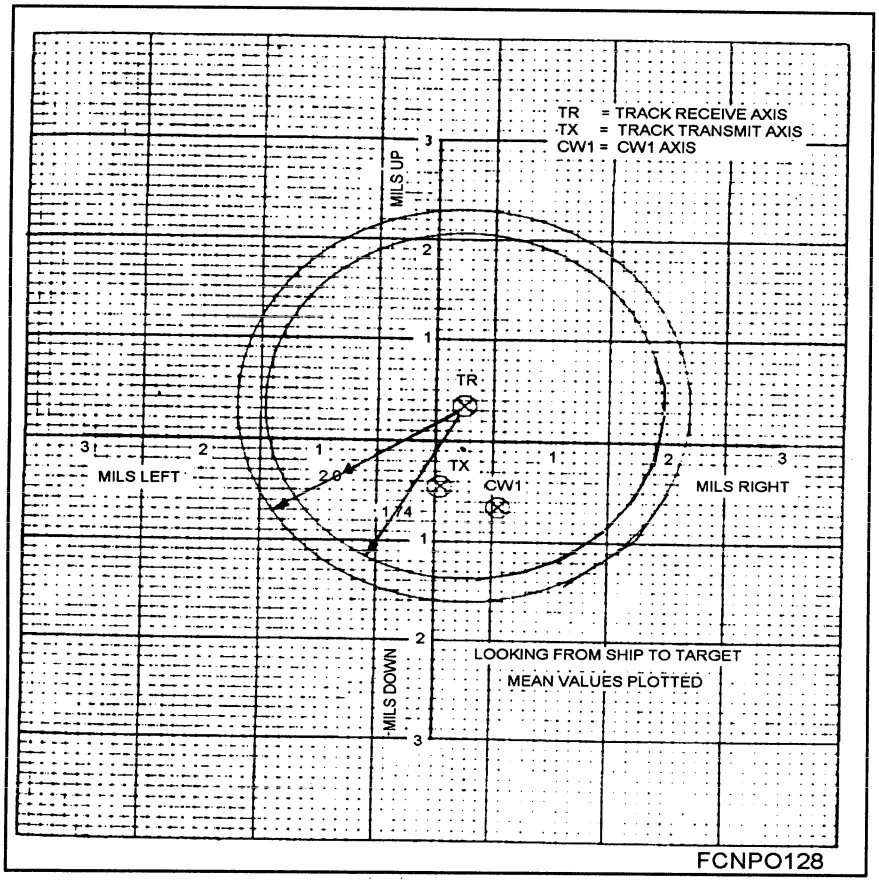


Figure 4-9.—Beam position summary graph.

RECOMMENDED READING LIST

NOTE: Although the following references were current when this TRAMAN was published, their continued currency cannot be assured. Therefore, you need to ensure that you are studying the latest revision.

Combat System Alignment Manual for DDG-51 Class, Alignment Verification and Corrective Alignment, NAVSEA SW225-CH-CSA-010, Naval Sea Systems Command, Washington, DC, 1993.

Combat System Alignment Manual for FFG-7 Class, Alignment Verification and Corrective Alignment Procedures, NAVSEA SW225-B6-CSA-010, Naval Sea Systems Command, Washington, DC, 1987.

Combat Systems Alignment Manual for your class of ship.